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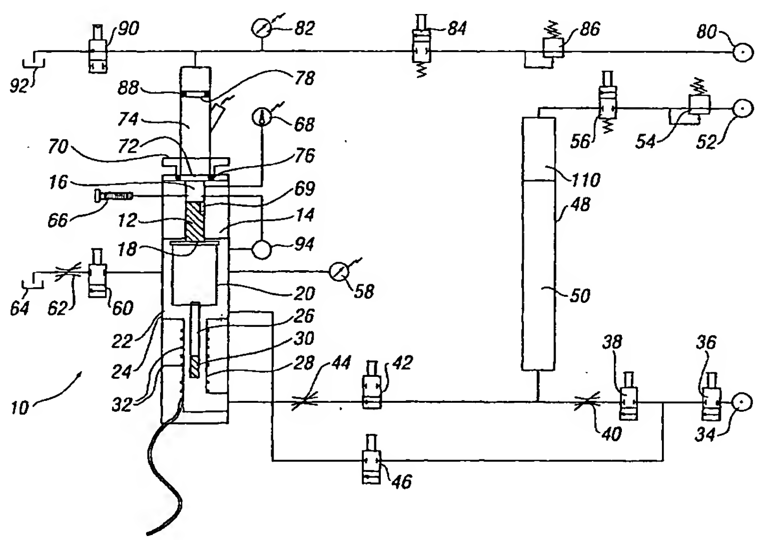
(54) **Title:** VOLUMETRIC MEASURING MEANS



(57) **Abstract:** Volumetric measuring means (10) comprising a piston and cylinder arrangement (12, 14) in which the cylinder (14) defines a metering chamber (16) having a port, to which a nozzle end (72) of a fuel injector (74) to be tested is connected and through which fluid flows when the measuring means (10) are in use, such that movement of the piston (12) within the cylinder (14), along the axis thereof, provides a measure of the volume of fluid which has passed through the said port. A displacement indicator (30, 32) is coupled to the piston (12) to provide an indication of the position thereof. The piston (12) is coupled to a float (20) in a flotation chamber (24) which is filled with fluid and which is in fluid communication with that side of the piston (12) opposite to that of the metering chamber (16).

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

Volumetric measuring means

The present invention relates to volumetric measuring means comprising a piston and cylinder arrangement in which the cylinder defines a metering chamber having a port, through which fluid flows when the measuring means are in use, such that movement of the piston within the cylinder, along the axis thereof, provides a measure of the volume of fluid which has passed through the said port, and a displacement indicator coupled to the piston to provide an indication of the position thereof.

An example of such volumetric measuring means as already proposed is described in DE-A-19809926.

Such a construction may be used especially to measure the rate of leakage of fluid from a fuel injector.

In this construction, there is a tight seal between the piston and the cylinder to ensure that there is no leakage of fuel or test fluid from the cylinder whilst a measurement is being made.

A disadvantage of such a construction is the friction between the piston and the cylinder that arises. This may increase the temperature of the test fluid by an uncertain amount, and this in turn may introduce errors in the reading given by the apparatus. Such a construction also requires a sensitive pressure transducer for the measurement process, which transducer is susceptible to damage.

The present invention seeks to reduce the extent to which the volumetric measuring means are subject to one or other of these disadvantages.

Accordingly, the present invention is directed to volumetric measuring means having the construction set out in the opening paragraph of the present specification, in which the piston has a precision fit within the cylinder, but is nonetheless of smaller cross-section, in which the piston comprises or is coupled to a float in a flotation chamber which is filled with fluid when the volumetric measuring means are in use, and which lies on the axis of the cylinder, in which the said axis is generally upright when the measuring means are in use, in which the flotation chamber is in fluid communication with that side of the piston opposite to that of the metering chamber, and in which the bouyancy of the float in the flotation chamber is such as to ensure that the pressure of fluid in the metering chamber is sufficiently close to that in the flotation chamber that the amount of any fluid which flows past the piston is negligible in comparison to the amount of fluid which flows through the said port.

It is desirable to have a buoyancy of the float which is such as to cause some bias urging the piston in the direction of the metering chamber.

Preferably, a fuel injector fixture is positioned at the said port to enable a fuel injector to have one of its ends sealed in fluid communication with the said

port.

The metering chamber may be above the flotation chamber when the volumetric metering means are in use.

Preferably, in this embodiment of the present invention, the said one of the ends of the fuel injector is the nozzle end. In that case, it is desirable to have a source of pressurized fluid arranged for connection to the inlet end of the injector. A purge and drain valve may also be arranged for connection to the inlet end of the injector to enable the metering chamber to be purged and drained. This avoids the need for any purging valve to be connected to the metering chamber downstream of the nozzle end of the fuel injector for purging purposes, which in turn avoids the risk that during a measurement when fluid leaks through the closed nozzle end of the fuel injector during use of the volumetric measuring means, that any leakage could also occur through the purging valve which could affect the measurement.

Such an embodiment of the present invention provides the advantage that there is no valve connected directly to the metering chamber which could give rise to a measurement error in the event that fluid leaks past such a valve.

In a further embodiment of the present invention, the volumetric measuring means are so constructed that the metering chamber is below the flotation chamber when the volumetric measuring means are in use.

Advantageously, with this embodiment of the present

invention, the said fixture is constructed to enable the inlet end of such an injector to be sealed in fluid communication with the metering chamber. This has the advantage that only one sealed connection needs to be provided for the injector.

Whichever embodiment is used, it is advantageous for the piston to have a passageway formed adjacent to its surface which forms a boundary of the metering chamber so that, as the piston approaches the end of its travel, a direct communication is provided between the metering chamber and the flotation chamber to ensure that the volumetric measuring means are not damaged by any overrun of the piston's travel, no hydraulic lock will occur, and a purge facility is provided.

Preferably, the displacement indicator comprises a non-contacting linear transducer, for example, an LDVT (linear differential voltage transformer).

Examples of volumetric measuring means embodying the present invention will now be described with reference to the accompanying drawings, in which:

Figure 1 is a diagram of a first embodiment of the present invention;

Figure 2 is an explanatory graph; and

Figure 3 is a diagram of a second embodiment of the present invention.

Figure 1 shows fuel-injector leak-rate measurement apparatus 10 comprising a piston 12 which forms a precision fit within a cylinder 14. The piston 12

nonetheless has a very slightly smaller cross-section than the internal cross-section of the cylinder 14. The interior 16 of the cylinder 14 defines a metering chamber, which, since it is also bounded by the piston 12, is of variable volume.

The piston 12 is able to slide axially within the cylinder 14 in a generally vertical direction. The lower end 18 of the piston 12 is rigidly connected to a rigid float 20 which in turn is wholly submersed in fluid 22 in a flotation chamber 24. The dimensions of the chamber 24 and the float 22 are such as to define the limits of the piston stroke.

A rigid rod 26 is connected rigidly to the lower end of the float 20. The rod 26 extends into a narrowed portion 28 of the flotation chamber 22. A lower end of the rod 26 is provided with an armature 30 which, together with coils 32 coiled around that narrowed portion 28 of the flotation chamber 22, forms a non-contacting linear transducer in the form of an LDVT. This enables the linear movement of the piston 12 within the cylinder 14 to be measured with precision. The narrowed end 28 of the flotation chamber 22 is connected to a source 34 of pressurized fluid via a number of valves connected in series in the following order from the source 34 to the chamber 22: a shut-off valve 36, a further shut-off valve 38, a fluid flow valve 40, a further shut-off valve 42 and a further fluid control valve 44. The main part of the flotation chamber 22 is

connected to the line between the two shut-off valves 36 and 38 via a further shut-off valve 46.

A fluid-containing column 48 extends in fluid communication with the line between the valves 40 and 42 for supporting a vertical column of fluid 50. The upper end of the column 48 is connected to a source of pressurized air 52 via a regulator 54 and a solenoid operated shuttle valve 56.

Also connected to the flotation chamber 22 is a pressure transducer 58 and a shut-off drain valve 60 which is in series with a fluid control valve 62 and a drain 64.

The cylinder 14 is provided with a micrometer screw gauge 66 to enable the metering chamber 16 to be calibrated. During calibration, the total displacement may occur over an extended period of time to reduce temperature effects.

A temperature transducer 68 is also connected to the measuring chamber 16.

The upper end of the piston 12 is provided with a flat 69. This provides a direct communication between the metering chamber 16 and the flotation chamber 22 to ensure that the apparatus is not damaged by any overrun of the piston's travel, no hydraulic lock will occur, and a purge facility is provided.

The upper end of the cylinder 14 is provided with a fixture 70 to which the nozzle end 72 of a fuel injector 74 to be tested is connected. The connection is made

fluid-tight by means of an O-ring seal 76.

The inlet end 78 of the fuel injector 74 is connected to a source 80 of high pressure fluid via a pressure transducer 82, a shut-off valve 84 and a regulator valve 86 connected in series with one another. The connection is made to the injector valve 74 via an O-ring seal 88.

A drain valve 90 is also connected to the inlet end 78 of the fuel injector 74 to enable fluid to be purged from the metering chamber 16 via the fuel injector 74 and the valve 90 to a collecting vessel 92.

A differential pressure gauge 94 may be connected to measure the pressure differential between the metering chamber 16 and the flotation chamber 22.

The equipment is prepared for measurement by inserting the fuel injector 74 to be tested into the volumetric measuring means as shown in Figure 1, with its inlet end sealed by the O-ring 88 and its nozzle end sealed by the O-ring 76. The system is then filled with test oil and purged of air by means of the flow control valves 40, 44 and 62 and the shut-off valves 36, 38, 42, 46, 60, 84 and 90, with the fuel injector 74 itself in an open condition.

With the system purged of air in this way (to ensure that no springiness in the system will give rise to a measurement error), and after the piston 12 has been allowed to rise to its upper end of travel by closing valve 84 and opening valve 90, pressurized test oil from

the source 80 is fed to the fuel injector 74 by closing valve 90 and opening valve 84. Initially, the fuel injector 74 is pulsed to feed test oil into the metering chamber 16, so as to take the piston away from its extreme end of travel where end effects could interfere with accuracy. The injector 74 is then held in its non-injecting state so that any test oil passing from the injector 74 into the measuring chamber 16 does so by way of leakage through the nozzle end 72. Clearly, the pressure of the test oil in the injector 74 is higher than it is in the metering chamber 16. This leakage lowers the piston 12, the precise displacement 70 being indicated by the LDVT constituted by the armature 30 on the rod 26, and the coil 32. The output from the LDVT is amplified, processed and captured using a microprocessor. Measurements taken from the LDVT at regular intervals of time provide an indication of the leak rate through the injector 74 as indicated in Figure 2, in which the horizontal axis shows time in seconds and the vertical axis represents the volume of test oil leaked into the measuring chamber 12 from the injector 74. The leakage volume is determined by the cross-section of the piston in the cylinder arrangement and the displacement of the piston 12.

These readings may be taken automatically by way of a microprocessor having a built-in timing device (not shown). At the same time, the inputs from the differential gauge 94, the temperature transducer 68 and

the temperature transducer 82 may be connected to the microprocessor to provide an indication of any corrections required in view of the readings from the pressure transducer 58, the differential gauge 94 and the temperature sensor 68, and also to provide an indication of the pressure as indicated by the pressure transducer 82 at which such leak rate occurs.

When the measurment process is complete, the shut-off valve 84 enables the source of test oil 80 to be shut-off, thus enabling the fuel injector 74 to be removed.

It will be appreciated that the nature of the fit of the piston 12 within the cylinder 14 is such that virtually no frictional heat is generated by movement of the piston within the cylinder. At the same time, because of the very gentle force urging the piston 12 in the direction of the metering chamber 16 by virtue of the buoyancy of the float 20, only slightly over-compensating for the weight of the piston 12, the float 20 itself and the rod 26, only a very low pressure differential exists between the metering chamber 16 and the flotation chamber 22, so that if there is any flow of test oil from the measuring chamber 16 to the flotation chamber 22, it is negligible.

It will be appreciated that the pressure in the flotation chamber 22 and the metering chamber 16 is maintained at a substantially constant level by the pressurized air 110 from the source 52 trapped in the

column 48 by the valve 56, to provide a substantially constant back-pressure whilst a measurement is being made.

In the modified construction shown in Figure 3, the piston and cylinder arrangement and the flotation chamber are inverted so that now the metering chamber 16 is below the flotation chamber 22. Furthermore, it is the inlet end of the fuel injector 74 which is connected to the fixture 70 so as to be in sealing engagement with the measuring chamber 16 by way of the O-ring 76. There is therefore no need for a sealing connection to be made to the nozzle end of the injector 74. For the sake of cleanliness and to avoid waste, however, a collecting vessel 100 is located underneath the nozzle end 72 of the injector 74.

To enable the purging process to be effected in this construction, a source of high pressure test oil 102 is connected to the metering chamber 16 via the shut-off valve 104. In this arrangement, the buoyancy created by the float 20 slightly under-compensates for the weights of the piston 12, the float 20 itself and the rod 26, so that the piston is gently urged towards the metering chamber 16.

Operation of the embodiment shown in Figure 3 is generally the same as operation of the embodiment shown in Figure 1, except that the measuring chamber 16 starts the measuring process filled by test oil from the source 102 thereof and measurements are taken at successive

intervals as the measuring chamber 16 empties as a result of leakage of test oil through the injector nozzle 72, whereas in Figure 1 it will be appreciated that the metering chamber 16 is filled by leaking fluid as the measuring procedure progresses.

It will also be appreciated in Figure 3 that the pressure of test oil applied to the fuel injector is determined by the trapped volume of gas 110 within the column 48 rather than the pressure of the test oil downstream of the regulator 86 as it is in Figure 1.

Numerous variations and modifications to the illustrated apparatus may occur to the reader without taking it outside the scope of the present invention. For example, the Figure 1 construction could be inverted without making the modifications to it shown in Figure 3, save only that the buoyancy of the float 20 would need to be adjusted to ensure that the piston is stil gently urged towards the metering chamber 74.

The illustrated volumetric measuring means may also be adpated to measure the leak rate of devices other than fuel injectors, which have critical liquid leak rate parameters.

It will be appreciated that the Figure 3 embodiment enables a measurement to be made of the fluid flow rate required to maintain the liquid inside the fuel injector at a stable pressure..

It will also be appreciated that the illustrated embodiments of the present invention involve relatively

small metering chambers, so that the volumes of fluid being measured are relatively small, and any errors owing to temperature fluctuations are correspondingly small.

The O-rings 76 and 88 may instead be flat rings.

Opening of the valves in the illustrated apparatus may be effected manually or automatically by appropriate electrical circuitry (not shown).

The embodiment of the present invention illustrated in Figure 3, and also the embodiment shown in Figure 1 to the extent that it is modified by the removal of the pressure differential transducer 94, provide the advantage that there is no sensitive pressure transducer connected directly to the metering chamber that could be damaged during use of the apparatus.

Even so the embodiment shown in Figure 3 could also be provided with a pressure differential transducer 94 as in the Figure 1 embodiment, to sacrifice the security against transducer damage for the benefit of being able to provide a measure of any pressure differential between the metering chamber 16 and the flotation chamber 22, and to correct the measurement to compensate for such pressure differential.

It will be appreciated that for larger flows to be measured, the piston 12 itself could be the float, so that the flotation chamber would be constituted by the interior of the cylinder 14 both above and below the piston 12, and the metering chamber would be constituted by that part of the flotation chamber which is above the

piston 12 in the case of the Figure 1 embodiment, and below the piston 12 in the case of the Figure 3 embodiment.

Claims:

1. Volumetric measuring means (10) comprising a piston and cylinder arrangement (12, 14) in which the cylinder (14) defines a metering chamber (16) having a port, through which fluid flows when the measuring means (10) are in use, such that movement of the piston (12) within the cylinder (14), along the axis thereof, provides a measure of the volume of fluid which has passed through the said port, and a displacement indicator (30, 32) coupled to the piston (12) to provide an indication of the position thereof, **characterised in that** the piston (12) has a precision fit within the cylinder (14), but is nonetheless of smaller cross-section, **in that** the piston (12) comprises or is coupled to a float (20) in a flotation chamber (24) which is filled with fluid when the volumetric measuring means (10) are in use, and which lies on the axis of the cylinder (14), **in that** the said axis is generally upright when the measuring means (10) are in use, **in that** the flotation chamber (24) is in fluid communication with that side of the piston (12) opposite to that of the metering chamber (16), and **in that** the bouyancy of the float (20) in the flotation chamber (24) is such as to ensure that the pressure of fluid in the metering chamber (16) is sufficiently close to that in the flotation chamber (24) that the amount of any fluid which flows past the piston (12) is negligible in comparison to the amount of fluid which flows through

the said port.

2. Volumetric measuring means according to claim 1, **characterised in that** the float (20) is buoyant.

3. Volumetric measuring means according to claim 2, **characterised in that** the buoyancy of the float (20) is such as to cause some bias urging the piston (12) in the direction of the metering chamber (16).

4. Volumetric measuring means according to any preceding claim, **characterised in that** a fuel injector fixture (70) is positioned at the said port to enable a fuel injector (74) to have one of its ends sealed in fluid communication with the said port.

5. Volumetric measuring means according to any precedng claim, **characterised in that** the metering chamber (16) is above the flotation chamber (24) when the volumetric metering means (10) are in use.

6. Volumetric measuring means according to claim 5, **characterised in that** the said one of the ends of the fuel injector (74) is the nozzle end.

7. Volumetric measuring means according to claim 6, **characterised in that** a source (80) of pressurized fluid is arranged for connection to the inlet end of the injector (74).

8. Volumetric measuring means according to claim 7, **characterised in that** a purge and drain valve (90) is also arranged for connection to the inlet end of the injector (74) to enable the metering chamber (16) to be

purged and drained.

9. Volumetric measuring means according to any one of claims 1 to 4, **characterised in that** the metering chamber (16) is below the flotation chamber (24) when the volumetric measuring means (10) are in use.

10. Volumetric measuring means according to claim 9, **characterised in that** the said fixture (70) is constructed to enable the inlet end of such an injector (74) to be sealed in fluid communication with the metering chamber (16).

11. Volumetric measuring means according to any preceding claim, **characterised in that** the piston (12) has a passageway (69) formed adjacent to its surface which forms a boundary of the metering chamber (16) so that, as the piston (12) approaches the end of its travel, a direct communication is provided between the metering chamber (16) and the flotation chamber (24).

12. Volumetric measuring means according to any preceding claim, **characterised in that** the displacement indicator (30, 32) comprises a non-contacting linear transducer (30, 32).

13. Volumetric measuring means according to claim 12, **characterised in that** the displacement indicator (30, 32) comprises a linear differential voltage transformer (30, 32).

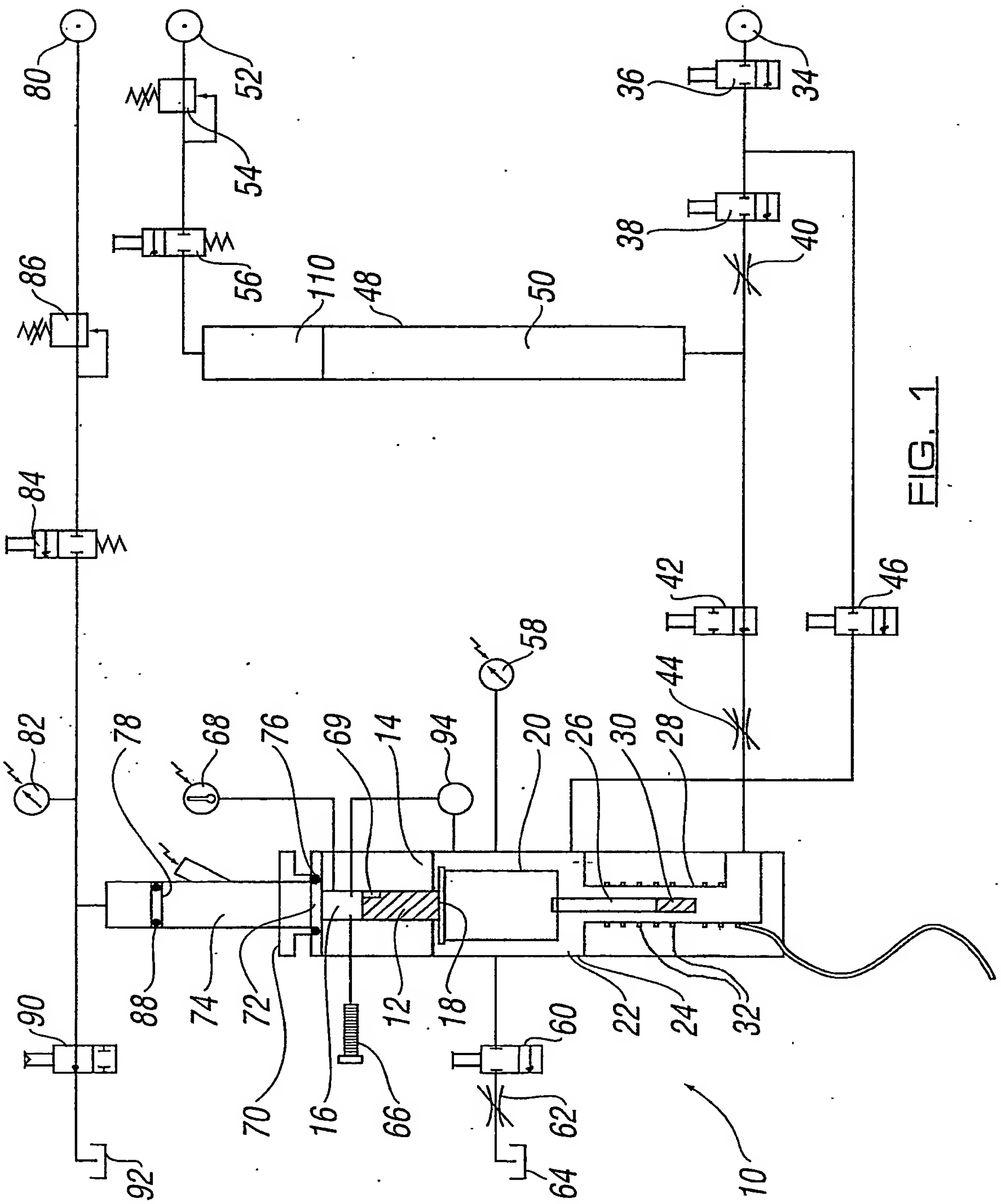

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FIG. 1

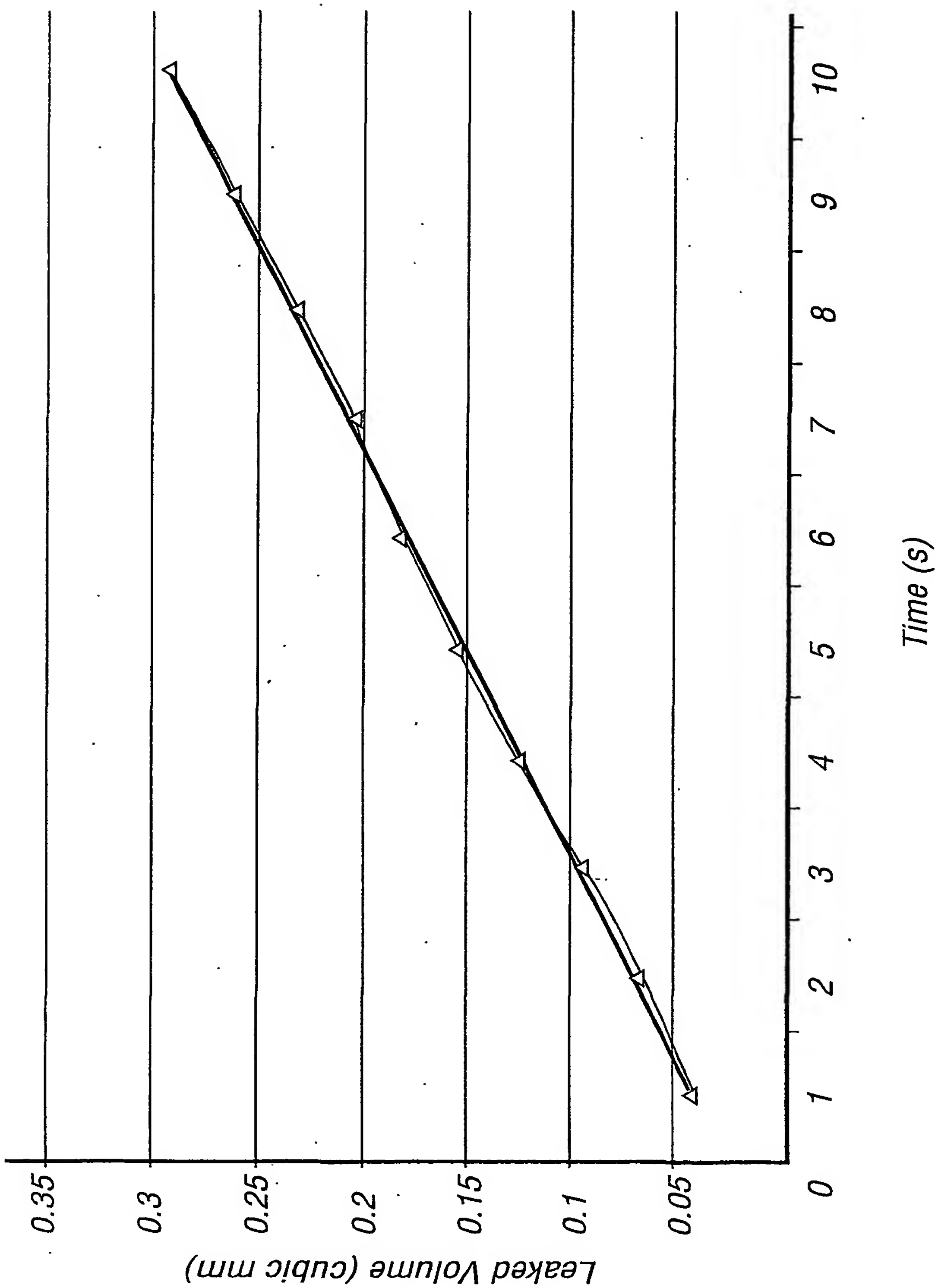
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FIG. 2

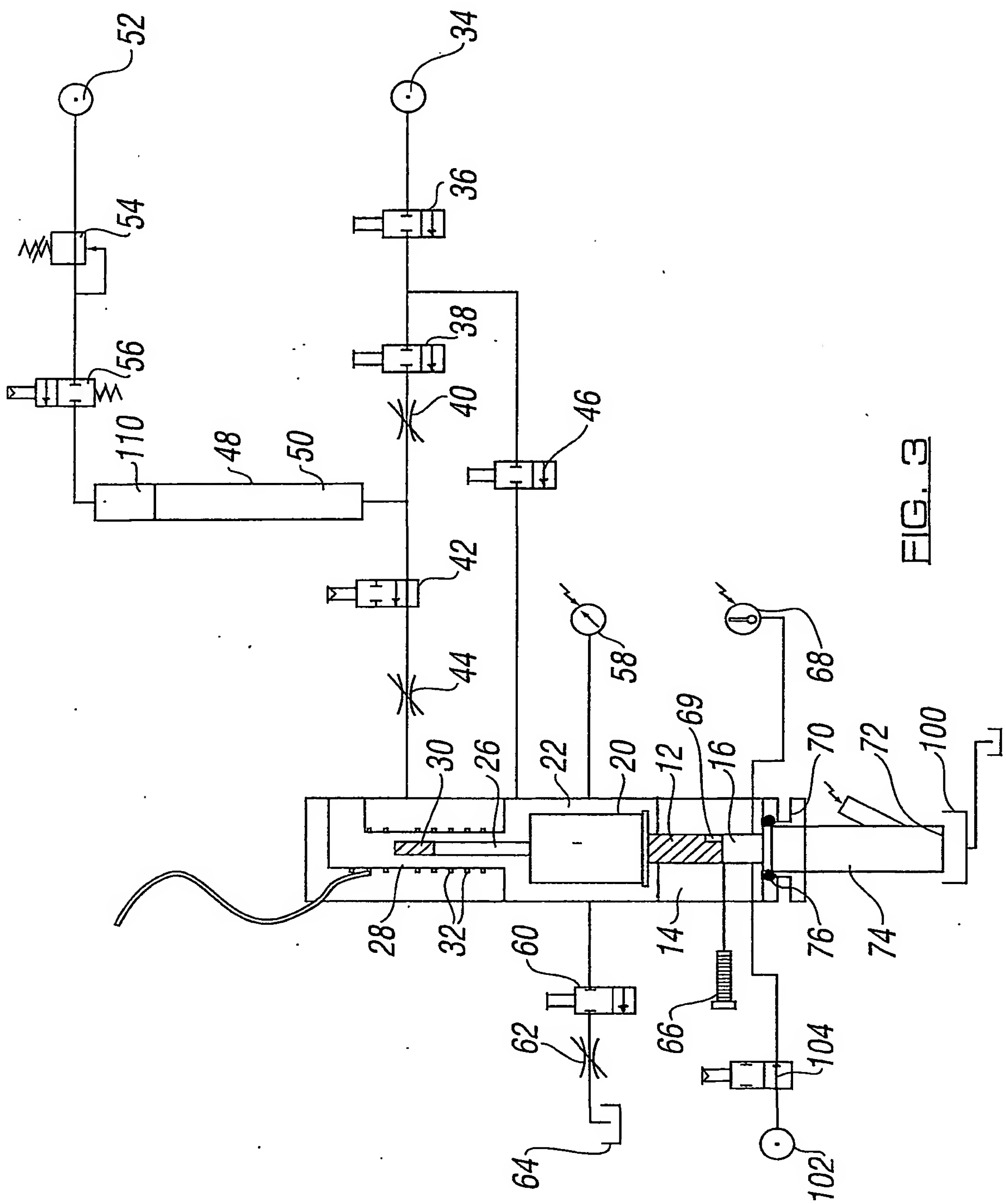
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FIG. 3

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 02/02607

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 F02M65/00 G01F3/16 G01F11/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 F02M G01F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	PATENT ABSTRACTS OF JAPAN vol. 1995, no. 08, 29 September 1995 (1995-09-29) & JP 07 119585 A (TOYOTA MOTOR CORP), 9 May 1995 (1995-05-09) abstract	1,4-7,9, 10,12
A	GB 2 293 626 A (BOSCH GMBH ROBERT) 3 April 1996 (1996-04-03) page 3, line 6 - line 35 page 10, line 13 -page 11, line 27; figures 1,5	1,4-7,9, 10
A	US 4 437 341 A (ITO SHINZO ET AL) 20 March 1984 (1984-03-20) column 2, line 28 -column 3, line 4; figure 2	1,4-7,9, 10,12,13

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
17 October 2002	04/11/2002

Name and mailing address of the ISA	Authorized officer
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INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 02/02607

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	GB 2 348 463 A (DAIMLER CHRYSLER AG) 4 October 2000 (2000-10-04) page 8, line 1 -page 9, line 8; figures 1,2	1,4-7,9, 10,12,13

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/GB 02/02607

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